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Progress in eradicating cats (*Felis catus*) on Christmas Island to conserve biodiversity

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Abstract. The impact of cats (*Felis catus*) on the biodiversity of Christmas Island is of significant concern to land management agencies and the broader community. In 2010, a management plan for cats, and also black rats (*Rattus rattus*), was commissioned that would mitigate the environmental and social impacts of these alien invasives across the island. A strategy was recommended that provided a staged approach to their management and control leading to eradication of one or both target species. For cats, Stage 1 initially involved gaining approval of revisions to the current local cat management laws that prohibited importation of new cats; this was then followed by a veterinary programme to de-sex, micro-chip and register all domestic cats. Stage 2 required removal of all non-domestic (i.e., stray/feral) cats within the residential, commercial and light industrial zones. Without implementation of Stage 2, a significant source of cats, particularly natal recruits, would be available to disperse into or reinvade territories vacated across the island. Stage 2 was required before an island-wide control programme (Stage 3) could be implemented.

Stage 1 of the programme has been completed with 135 domestic cats currently registered. Stage 2 has led to the majority of stray/feral cats being destroyed within the residential, commercial and light industrial area. Two hundred and seventy-eight stray/feral cats were removed from this area since May 2011, primarily through cage-trapping. Two baiting programmes have been conducted around the periphery of the residential area with between 36–49 cats being removed in 2011 and a further 103–142 stray/feral cats poisoned during a more extensive programme in 2012. The combined trapping and baiting programmes have resulted in between 417–469 stray/feral cats being removed since the commencement of the plan. Continued funding is essential for a successful conclusion to the cat eradication programme on the island.

Key words. cats, *Felis catus*, eradication, trapping, baiting

INTRODUCTION

There is extensive evidence that the introduction of domestic cats (*Felis catus*) to both offshore and oceanic islands around the world can have deleterious impacts on endemic land vertebrates and breeding bird populations (Ratcliffe et al., 2009; Bonnaud et al., 2010). Feral cats have been known to drive numerous extinctions of endemic species on islands and have contributed to at least 14% of all 238 vertebrate extinctions recorded globally by the IUCN (Nogales et al., 2013). In addition, predation by feral cats currently threatens 8% of the 464 species listed as critically endangered (Medina et al., 2011; Nogales et al., 2013). Island fauna that have evolved for long periods in the absence of predators are particularly susceptible to cat predation (Dickman, 1992). Christmas Island—a high biodiversity island—is no exception.

Four of the five mammal species that were present on the island at settlement in 1888 have since become extinct. The diurnal native bulldog rat (*Rattus nativitatus*) and nocturnal Maclear's rat (*R. macleari*) were reportedly common at the time of settlement and are both extinct; the Christmas Island shrew (*Crocidura attenuata trichura*) has not been seen since 1985 and is believed extinct (Beeton et al., 2010). Recently in 2009, the Christmas Island pipistrelle (*Pipistrellus murrayi*) became extinct (Martin et al., 2012). While several factors, including disease, habitat destruction (land clearing and natural catastrophes such as cyclones) and the proliferation of the exotic yellow crazy ant (*Anoplolepsis gracilipes*), are likely to have contributed to the demise of these native animals, the introduction of exotic competitors and predators such as the cat and black rat (*R. rattus*) are also crucial factors.

A recent Parks Australia report (Parks Australia, 2008) lists five extant Christmas Island species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) which are likely to be adversely affected by cats and/or rats and would likely benefit from their eradication: the emerald dove (*Chalcophaps indica natalis*), Christmas Island hawk-owl (*Ninox natalis*), Christmas Island thrush (*Turdus poliocephalus erythropleurus*), Lister's gecko (*Lepidodactylus listeri*), and pink blind snake (*Typhlops*

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exocoeti). Other species considered at risk from cat predation include the blue-tailed skink (*Cryptoblepharus egeriae*) and forest skink (*Emoia nativitatis*), which are not yet listed under the EPBC Act as threatened but are rapidly declining and under threat of extinction. In addition to these species, Beeton et al., (2010) indicated that the white-tailed tropicbird (*Phaethon lepturus fulvus*) and Christmas Island white-eye (*Zosterops natalis*) were also threatened by cat and rat predation and there was also concern about cat predation on brown booby chicks (*Sula leucogaster*).

Cats were taken to Christmas Island during first settlement in 1888 (Tidemann et al., 1994) which resulted in an abundant feral population being present across the island. There was also a large domestic and stray cat population within the residential area. The impact of cats in particular, and also rats, on the biodiversity of Christmas Island was of significant concern to land management agencies and the broader community. As a consequence, a 'Management Plan for Cats and Black Rats on Christmas Island' (Algar & Johnston, 2010) was commissioned that would mitigate the environmental and social impacts of cats and black rats across all land tenures (shire-managed lands, Crown land including mine leases and Christmas Island National Park). The management strategy recommended a staged approach to their control leading to eradication of one or both target species.

In 2010, suggested revisions to the current local cat management laws (Shire of Christmas Island Local Law for the Keeping and Control of Cats 2004) under the Local Government Act 1995 (WA) (Ci) were adopted. These revisions to the cat management law prohibited importation of new cats and required the provision of a veterinary programme to de-sex, micro-chip and register all domestic cats (Stage 1). Cat registration was essential as it would: (i) ensure the release rather than destruction of domestic cats during trapping campaigns for stray and feral cats and (ii) ensure the de-sexing of all domestic cats to prevent potential natal recruitment into the domestic, stray and feral populations. Three veterinary programmes were required to complete the necessary work and were conducted in October 2010, May 2011 and a final programme in May 2012. Veterinary services were provided free to the owners of domestic cats at a total cost to the eradication programme of less than US$10,000 each year.

The primary aim of Stage 2 of the management plan was to remove all stray cats within the residential, commercial and light industrial zones of Christmas Island. This also included cats at the Immigration Detention Centre (IDC), both at North West Point (NWP) and Phosphate Hill precinct. Cage trapping has been the primary control technique employed to remove these cats followed by targeted use of leg-hold trapping. A baiting programme along the roadsides/tracks that surrounded the residential and light industrial area was also conducted during late September–October 2011. Without implementation of Stage 2, a significant source of cats, particularly natal recruits, would be available to disperse into or reinvade territories vacated across the rest of the island (i.e., the national park and Unallocated Crown Land). Stage 2 was conducted over the periods May–October 2011, February and May–August 2012 at a total cost of approximately US$500,000. Stage 2 was required before an island-wide control programme (Stage 3) could be implemented.

Unfortunately the funding application for commencement of Stage 3 (June 2013 onwards) was not granted. Following this decision, the various agencies involved recommended that a second more intensive baiting programme be conducted outward from the residential area to remove the majority of individual animals adjacent to the residential area and provide a buffer zone into which dispersing cats would move. This control effort, included in the above costing, was conducted during June–August 2012 and would protect the significant investment and gains in controlling stray cats achieved during Stage 2 until further funding could be obtained.

This paper reports on cat control and documents the activities in chronological order over the above period. Also included are the surveys for domestic cats and subsequent veterinary programmes. The reaction of the local community to the cat control campaign, improved nesting success of the two tropicbird species as a likely consequence of this early cat control effort and the cost of cat eradication are also discussed.

MATERIAL AND METHODS

Site description. Christmas Island is located in the Indian Ocean (10°25'S, 105°40'E) approximately 2800 km west of Darwin, 2600 km north-west of Perth, and 360 km south of the Indonesian capital of Jakarta. The island has an area of approximately 135 km^2 and was formed from an undersea volcano that rose to the surface and has since subsided and risen over geological time. The oceanic island is composed primarily of Tertiary limestone overlying volcanic andesite and basalt (Tidemann et al., 1994; Environment Australia, 2002). The island rises steeply from the surrounding ocean and consists of a series of fringing limestone terraces, separated by rugged limestone cliffs and scree slopes, rising to an internal central plateau at about 200 m and extending to 360 m above sea level.

The location of work conducted during this current programme was primarily confined to the north-east corner of the island within the residential, commercial and light industrial areas. However, trapping was also conducted within and surrounding the Immigration Detention Centre at North West Point. Baiting programmes were also conducted outward from this general area.

Christmas Island has a typical tropical, equatorial climate with a wet and a dry season. The wet season is from December to April when the north-west monsoon blows and about 60% of the annual rainfall occurs (Bureau of Meteorology, 2009). For the rest of the year south-east trade winds bring slightly lower temperatures and humidity, and much less rain. Although the seasons are distinct, south-easterly winds may occur in the wet season and some rain may fall in any month of the year. The mean annual rainfall is 2154 mm

(Bureau of Meteorology, 2009). Most rain falls between November and May with February and March being the wettest months while August, September and October are the driest months. Mean daily temperatures are 23–28°C in March and April and 22–26°C in August and September (Bureau of Meteorology, 2009). Temperature varies little from month to month. The mean daily maximum is 28°C in March–April and the mean daily minimum is 22°C in August–September. Humidity also varies little between months and usually ranges from 80–90%.

Domestic cat survey. The 'Management Plan for Cats and Black Rats on Christmas Island' (Algar & Johnston, 2010) proposed a strategy to eradicate cats entirely from the island as the de-sexed domestic population died out. Cat registration was an essential first stage to this outcome. To ensure that all domestic cats were registered, it was necessary to conduct a survey for domestic cats across the entire residential area before the commencement of the veterinary programme. The survey process involved door-knocking at each permanent residence and questioning the adult inhabitants as to whether they had any domestic cats. All residences were surveyed and, as added insurance, neighbours were also asked whether domestic cats were present in adjoining houses. All surveyed people were informed of the risk of not declaring the presence of a domestic cat and it not being subsequently registered. The survey recorded the number of owned cats per household, the sex, age, coat colour and whether the animal had been de-sexed previously.

The first survey for domestic cats was conducted in October 2010 with subsequent surveys conducted in May 2011 and the latest in May 2012. These surveys were undertaken prior to the commencement of further veterinary programmes.

Veterinary programmes. The first veterinary programme was conducted in October 2010 (see Algar et al., 2011b). The second veterinary programme, conducted in May 2011, was required because four domestic cats were greater than five weeks pregnant and could not be de-sexed safely during the first veterinary programme. These animals were to be treated with a contraception injection following the birth and euthanasia of the kittens and spayed on a return visit by the veterinarian. A third veterinary programme was conducted in May 2012; this was the final programme that would be conducted on the island. Any further cats trapped or located would be destroyed. The protocols followed during the veterinary programme in October 2010 (see Algar et al., 2011b) were adopted during these subsequent veterinary programmes.

Trapping programmes. The registration and de-sexing of domestic cats was the first stage of the management plan (Algar & Johnston, 2010), with the second stage—the control of stray and feral cats in the residential, commercial and light industrial area—then able to proceed. The trapping programme commenced in June 2011 and continued through till mid October 2011. A brief trapping programme was conducted in February 2012 during a visit that was primarily undertaken to commence a rat baiting exercise. A more comprehensive trapping programme recommenced in May 2012 and continued through to mid August 2012. Trap sites were selected based on local knowledge of areas frequented by stray/feral cats, as well as areas deemed to be attractive to the target species. In addition, as the programme progressed and island residents witnessed its success, we were often informed by the general public of potential trap locations where cats had been seen. Traps were strategically located within these sites, typically in areas likely to be food sources and thoroughfares.

The trapping programme initially used cage traps rather than padded leg-hold traps to minimise the risk of injury to domestic cats. Cats were captured using Sheffield wire cage traps (60×20×20 cm) with treadle plates (Sheffield Wire Products, Welshpool, Australia). These traps were generally operated over five-day periods. All traps were covered with a hessian sack to provide shelter and protection to the captured animals until they could be collected. The traps were usually baited with cooked chicken wings (occasionally with fresh mulies [pilchards]) which were treated with the insecticide Coopex® to maintain the longevity of the bait by deterring ants from consuming or spoiling the bait. The baits were cable-tied to the back of the cage to reduce trap failures by increasing the time animals spent inside a cage, thus increasing the likelihood of activating the treadle mechanism. Baits were replaced as necessary.

Trapping with cage traps became ineffective towards the end of July 2012. Stray cats that remained were wary of this trap type probably as they had witnessed other cats being caught or they themselves had been trapped and released by the occasional errant member of the public tampering with the traps. Further trapping of stray cats was conducted using padded leg-hold traps (Victor 'Soft Catch' traps No. 3; Woodstream Corp., Lititz, PA, U.S.A.). A mixture of cat faeces and urine or the synthetic olfactory lure Cat-astrophic (Outfoxed Pest Control, Victoria) was used as the attractant. The traps were deployed on raised platforms to prevent crab access. They were installed either as single units on top of sand-filled 20 l buckets in "one-way" trap sets or in pairs on top of sand-filled truck wheel rims in "walk-through" trap sets. The leg-hold traps were deployed strategically in localised areas where problem cats remained and inspected at dawn and dusk.

Trapped feral cats were euthanised by an intercardial lethal injection (Lethabarb; Virbac, Australia). All animals captured were sexed, weighed and a broad estimation of age (as either kitten, juvenile or adult) was recorded according to their weight as a proxy for age. In addition, the pregnancy status of females was also used to determine whether the animal was an adult. The smallest weight recorded for a female that had recently given birth, at a time when sexually mature females had bred, was 2.0 kg and this was used as the minimum adult weight for female cats. The weight groupings for the cat age classes are provided in Table 1.

Baits and baiting programmes. The feral cat baits (Eradicat®) used were manufactured at the Department of

Table 1. The weight groups for the cat age classes of the trapped population.

Category	Male Weight /kg	Female Weight /kg
Kitten	<1.0	<1.0
Juvenile	1.0–2.4	1.0–1.9
Adult	≥2.5	≥2.0

Parks and Wildlife (formerly Department of Environment and Conservation) Bait Manufacturing Facility at Harvey, Western Australia. Frozen baits were transported to Christmas Island and then kept in frozen storage. The bait is similar to a chipolata sausage in appearance, approximately 20 g wet-weight, dried to 15 g, blanched and then frozen. This bait is composed of 70% kangaroo meat mince, 20% chicken fat and 10% digest and flavour enhancers (Patent No. AU 781829) (see detailed description in Algar & Burrows, 2004; Algar et al., 2007). Toxic feral cat baits were dosed at 4.5 mg of sodium monofluoroacetate (compound 1080) per bait. Prior to bait application, feral cat baits were thawed and placed in direct sunlight on-site. This process, termed 'sweating', causes the oils and lipid-soluble digest material to exude from the surface of the bait. All feral cat baits were sprayed, during the sweating process, with an ant deterrent compound (Coopex®) at a concentration of 12.5 g l^{-1} as per the manufacturer's instructions. This process prevents bait degradation by ant attack and enhances acceptance of baits by cats through limiting the physical presence of ants on and around the bait medium.

Previous research on Christmas Island has shown that terrestrial non-target species on the island, such as robber crabs (*Birgus latro*), black rats and feral chickens (*Gallus gallus domesticus*) would have monopolised the baits if they were laid on the ground, greatly reducing the number of baits available to feral cats (Algar & Brazell, 2008). These authors demonstrated a device to suspend baits above the ground that effectively stopped bait removal by non-target species yet provided ready access to feral cats.

In late September–October 2011 a network of these 'Bait Suspension Devices' (BSDs) was established along approximately 18 km of roadsides/tracks that surrounded the residential and light industrial area. No baits were laid within at least 1 km of the closest residence that had a domestic cat to prevent these animals being accidentally poisoned by consuming the baits left for the stray/feral cats. BSDs were located at 100 m intervals on both sides of the road/track, staggered at 50 m intervals across the road/track (Fig. 1). A bait, comprising two Eradicat® sausages tied at the link, was suspended at a height of about 400 mm from each BSD using 6–8 lb fishing line. Unlike previous programmes where a 1 m^2 'sand pad' of crushed phosphate dust was created underneath each BSD to enable the identification of species visiting the site, only BSDs on one side of the road/track had sand pads.

All BSDs were inspected daily over the 20-day baiting period to assess whether baits had been removed. To minimise the amount of toxic baits used, all BSDs were fitted initially with non-toxic baits until a bait had been removed. Baits at this BSD were then replaced with toxic baits.

Bait removal from the BSDs was used to determine the efficacy of the baiting programme. It was expected that a non-toxic bait would be taken by a cat, which would then subsequently return and remove a toxic bait. Replacement baits would continue to be provided until no further baits were removed. Baits were also routinely replaced each week because phosphate dust raised by passing vehicles adhered to the baits and was considered likely to reduce palatability.

A second, more extensive baiting was conducted in June–August 2012. This baiting programme adopted recommendations provided in an earlier report (Algar et al., 2011a). In this programme only toxic baits were used, baiting along major roads was conducted over 10 consecutive days and for five consecutive days along rainforest tracks. In addition, a number of baits stations were strung along walk trails. The locations of BSDs in 2012 are presented in Fig. 2.

As bait station activity cannot be ascribed to individual feral cats, a value for the maximum and minimum number of cats poisoned was determined. The total number of toxic baits removed was considered to indicate the maximum number of individuals poisoned. The minimum number of individuals poisoned was calculated by ascribing bait removals from consecutive BSDs to the same animal, even if ten or more stations were involved. The actual number of feral cats poisoned during these two programmes would be between these two extremes. It was considered likely that some cats would visit multiple BSDs given the delay between bait consumption and onset of symptoms.

RESULTS

Domestic cat surveys. One hundred and fifty-two cats (72 females, 80 males) were recorded during the initial survey in October 2010 of which 136 were registered as domestic pets (Algar et al., 2011b). A total of 17% (90 households) of all the permanent residential houses on Christmas Island (n = 526) owned one or more domestic cats. The majority

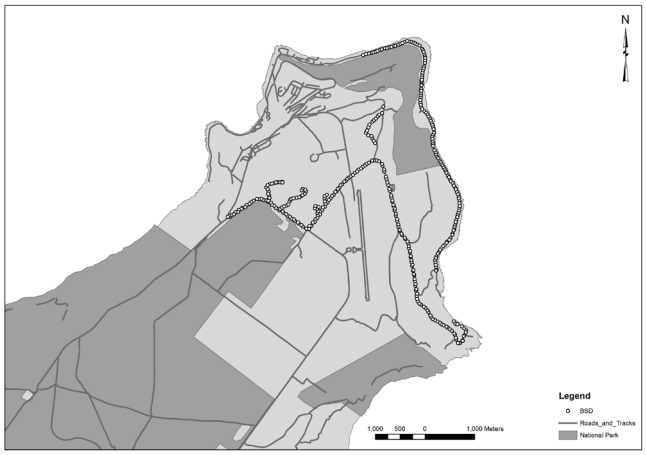

Fig. 1. Network of BSDs surrounding the residential and light industrial area in 2011.

Table 2. The age classes of the trapped population.

Trapping Period	Category	Male	Female	Total
May–October 2011	Kitten	9	25	34
	Juvenile	18	23	41
	Adult	45	74	119
February 2012	Kitten	0	5	5
	Juvenile	3	8	11
	Adult	2	6	8
May-August 2012	Kitten	2	9	11
	Juvenile	6	11	17
	Adult	16	16	32
Overall Total	Kitten	11	39	50
	Juvenile	27	42	69
	Adult	63	96	159

of households (73%) out of these households owned only one cat, with three households owning more than four cats (n = 5, 6, 8) (Algar et al., 2011b).

The survey for domestic cats conducted in May 2011 revealed that of the 136 previously registered domestic cats, 16 (seven females, nine males) had died between the first and second survey periods. These animals had either died from natural causes, road fatalities or were destroyed as the owners had moved off island.

At the completion of the veterinary programme conducted in May 2011 (see below), there were 138 registered domestic cats (69 females, 69 males). The third survey for domestic cats conducted in May 2012 indicated that of these registered animals, 15 (eight females, seven males) were no longer present. Of these cats, seven were road fatalities, five had been exported to the mainland and three had died of natural causes or had been euthanised.

Veterinary programmes. During the first veterinary programme, 16 cats (six females, 10 males) of those identified in the survey were unwanted animals and were euthanised. One hundred and thirty-six were micro-chipped and 31 of these cats needed to be de-sexed (nine females, 22 males).

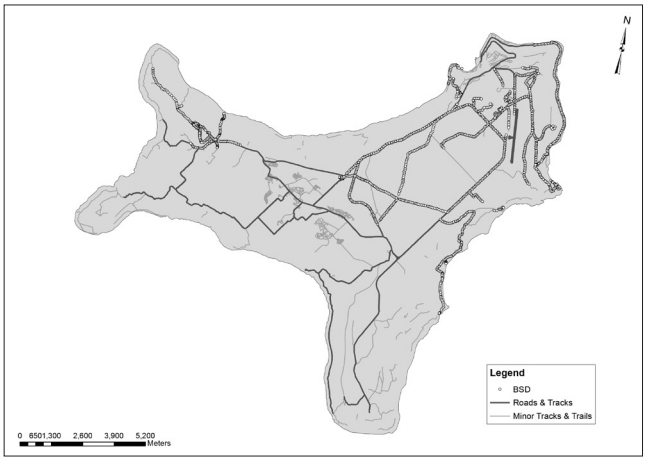

Fig. 2. Network of BSDs in 2012.

Unfortunately, two of the four pregnant cats that could not be de-sexed safely during the first veterinary programme in October 2010 were not administered with a contraception injection following the birth of the kittens and a second litter of kittens was produced by both cats prior to the second veterinary programme. Of 18 kittens/juveniles still alive, three kittens were euthanised; the other 15, along with the four female cats were de-sexed and registered. One female cat registered the previous year was euthanised following a request by the owner. Thus at the completion of the veterinary programme in May 2011, there were 138 registered domestic cats (69 females, 69 males).

The final veterinary programme conducted in May 2012 resulted in the registration of a further 12 cats (five females, seven males). Consequently, at the completion of the veterinary programmes there were 135 registered domestic cats (66 females, 69 males) on the island.

Trapping programmes. In 2011, 5121 cage trap-nights were conducted across the residential, commercial and light industrial areas. The trapping programme resulted in the removal of the majority of cats from this area, in total 194 stray/feral cats (122 females, 72 males), a biomass of 458.5 kg. Following the removal of these animals, a more strategic trapping programme was conducted in 2012, focusing in areas where cats had been observed or reported. The programme commenced in February when a limited trapping cage trapping programme (149 cage trap-nights) was conducted during the roll-out of the rat baiting programme. This trapping programme resulted in the removal of another 24 stray/feral cats (19 females, five males). The trapping programme was reconvened in May and continued through to the end of July (451 cage trap-nights). Trapping over this three-month period resulted in a further 52 stray/feral cats (32 females, 20 males) being destroyed. Thus in total, the cage trapping programme conducted over the period 2011–2012 has resulted in the removal of 270 stray/feral cats (173 females, 97 males), a biomass of 635.3 kg.

Trapping with cage traps was replaced with the use of padded leg-hold traps towards the end of July 2012. Initially they were installed as single units on top of sand-filled 20

Table 3. The location of captures and number of cats removed.

Location	Time Period			Total Number
	May–October 2011	February 2012	May–August 2012	
Tip, Rec. Centre, IDC (Phosphate Hill)	66	11	15	92
Drumsite	48	0	22	70
IDC (North West Point)	15	0	0	15
Poon Saan + Silvercity	28	12	6	46
Kampong, Club Rd. Flying Fish Cove	22	0	10	32
Settlement	11	1	7	19
Casino	4	0	0	4

l buckets in "one-way" trap sets; these were then replaced with paired traps on top of sand-filled truck wheel rims in "walk-through" trap sets. This trapping programme (57 leg-hold trap-nights) resulted in the removal of an additional eight stray/feral cats (four females, four males), a biomass of 24.1 kg. The only injuries incurred by trapped cats were slight foot oedemas with no lacerations.

The general location of all trap points, trap numbers and dates of commissioning and decommissioning are presented elsewhere (see Algar & Hamilton, 2012). The age classes of the trapped stray/feral cat population, for the various trapping periods, are provided in Table 2 and the general location of captures in Table 3 and Fig. 3.

The male-to-female sex ratio of the total trapped stray/feral cat population was 0.57, which differed significantly from unity ($\chi^2 = 20.78$, df = 1, $p < 0.001$). This was the case for all age classes (kittens, $\chi^2 = 15.68$, df = 1, $p < 0.001$), (juveniles, $\chi^2 = 3.66$, df = 1, $p < 0.05$) and (adults, $\chi^2 = 7.23$, df = 1, $p < 0.01$).

Of the 74 adult female cats destroyed in 2011, 44 (59%) were pregnant, 12 (16%) were lactating, 16 (22%) were non-pregnant/non-lactating and two (3%) had been de-sexed. Of the 22 adult females destroyed in 2012, six (27%) were pregnant, four (18%) were lactating, 12 (55%) were non-pregnant/non-lactating.

While conducting the trapping programme, 26 registered cats were trapped and returned to their owners, five of these animals were captured twice and one animal three times.

Baiting programmes. In 2011, bait removal was recorded at 110 of the 365 BSDs (30%) over the 20-day baiting period. Of these, baits were removed at 44 BSDs on more than one night (40%)—sometimes several times over the baiting period—while baits were removed at 66 BSDs on one night only (60%). One hundred and sixty-four baits were removed by feral cats over this period, of which 49 (30%) were toxic (Fig. 1).

In 2012, 1633 bait stations were established—1130 on BSDs over a ten-day period, 408 on BSDs over a five-day period and a further 95 left in place on walk trails. Bait removal was recorded at 110 of the 1538 BSDs (7%) over the baiting period. Of these, baits were removed at 25 BSDs on more than one night (23%)—sometimes several times over the baiting period—while baits were removed at 84 BSDs on one night only (77%). One hundred and forty-two toxic baits were removed by feral cats over this period (Fig. 4).

In 2011, the total number of toxic baits removed, and by inference the maximum number of individual feral cats poisoned, was 49. The minimum number of cats poisoned was 36 (Fig. 4), allowing for individual cats that may have consumed baits from multiple BSDs. In 2012, the total number of toxic baits removed, and by inference the maximum number of individual feral cats poisoned, was

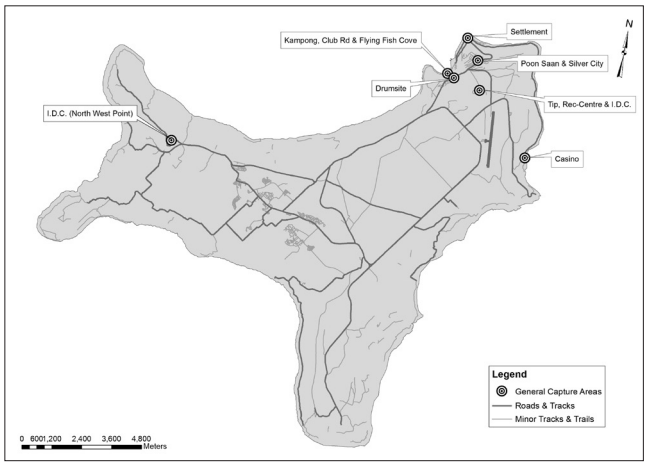

Fig. 3. Map of general location of trapped cats.

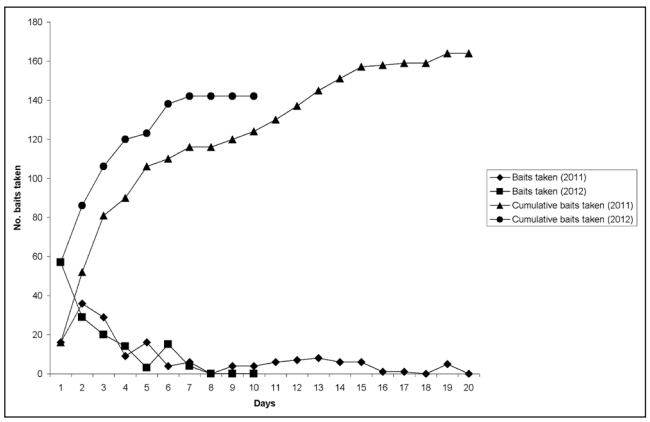

Fig. 4. Number of baits removed from BSDs by feral cats in 2011 and 2012.

Table 4. Number of stray/feral cats removed by each of the control methods.

Time Period	Control method			Total
	Cage traps	Leg-hold traps	Baiting	
May–October 2011	194	–	36–49	230–243
February 2012	24	–	–	24
May–August 2012	52	8	103–142	163–202
Total	270	8	139–191	417–469

142. The minimum number of cats poisoned was 103 (Fig. 5), allowing for individual cats that may have consumed baits from multiple BSDs.

In 2011, there were 28 occurrences when consecutive baits were removed from adjoining BSDs on the same day (data for major roads only, not the narrower tracks). On 13 of these occasions, bait removal occurred on both sides of the road and on 15 occasions, bait removal was restricted to one side of the road only. In 2012, there were 24 occurrences when consecutive baits were removed from adjoining BSDs on the same day. On 15 of these occasions, bait removal occurred on both sides of the road and on nine occasions, bait removal was restricted to one side of the road only.

The number of stray/feral cats removed by each control method, used over the periods May–October 2011, February and May–August 2012, is summarised in Table 4.

DISCUSSION

The final registration of all domestic cats was completed in May 2012 and resulted in 135 owned cats being registered within the residential area of Christmas Island. The surveys for domestic cats conducted over the past three years suggest that the 'model of domestic cat decrease over time', based on an average lifespan of 15 years, is underestimated. The model indicated that domestic cats would no longer be present on Christmas Island by 2024 (Algar et al., 2011b); however, the attrition rate is higher than predicted, particularly because of road fatalities, and the island is likely to be free of domestic cats much earlier.

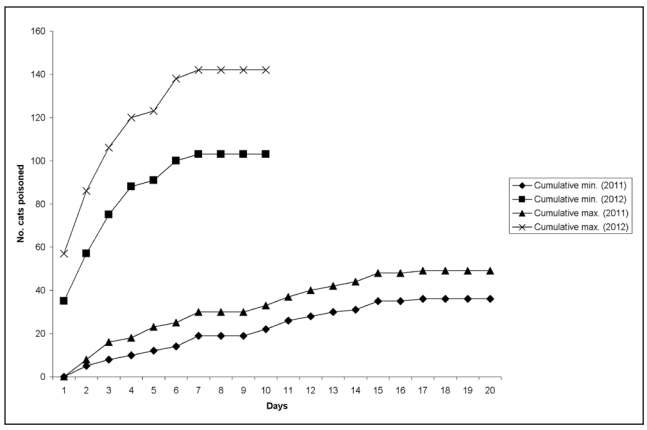

Fig. 5. Estimated cumulative minimum and maximum number of feral cats poisoned following consumption of toxic Eradicat® bait(s) in 2011 and 2012.

The substantial cat control effort conducted in the residential, commercial and light industrial area since June 2011, primarily through cage trapping and more recently with targeted leg-hold trapping, has removed 278 stray/feral cats from the area. This successful campaign has led to the majority of stray/feral cats being destroyed within this zone. This will now enable the adoption of a more strategic focused approach in future trapping programmes, particularly through the use of leg-hold traps, to remove the few remaining stray/feral cats.

An additional benefit of the de-sexing programme in conjunction with removal of so many stray/feral cats through trapping appears to be the reduction in the incidence of pregnancy in the adult stray/feral female cat population in 2012. With the number of entire males present in the population declining, the proportion of pregnant stray/feral female cats captured in 2012 was much lower compared with those of 2011, albeit in a smaller population sample.

The two baiting programmes have demonstrated that control/eradication of the feral cat population on Christmas Island is feasible using Eradicat® baits delivered on BSDs. The 2011 baiting programme, along 18 km of roadside/track around the periphery of the residential area, removed between 36 and 49 cats over the baiting period. The more extensive baiting programme in 2012 resulted in the removal of another 103–142 stray/feral cats along approximately 78 km of roadside/track. As a consequence of the combined trapping and baiting programmes, between 417 and 469 stray/feral cats (excluding in utero kittens) have been removed since the commencement of the plan.

The benefits of cat removal are already being observed particularly in the residential area where the majority of control effort has been focused. Studies of the red-tailed tropicbird (*Phaethon rubricauda*) in 2005–2006 indicated almost complete breeding failure (Ishii, 2006). In 2011, for the first time in a number of years, there was a dramatic increase in the nesting success rate of red-tailed tropicbird chicks along the Settlement shoreline (Algar et al., 2012). On Christmas Island, both domestic cats (identifiable by collars) and stray/feral cats have been photographed predating red-tailed tropicbird chicks. The euthanasia of a number of unwanted pet cats from residences along the Settlement shoreline in October 2010 and removal of a number of stray/feral cats from the same area prior to the nesting season is likely responsible, at least in part, for the improvement in the status of this spectacular species (Algar et al., 2012). Further removal of stray/feral cats from the Settlement shoreline area

in 2011 and 2012, the decline in domestic cats resident in the area and the implementation of a rat baiting programme have resulted in further increases in nestling success in 2012 for the red-tailed tropicbird (N. Hamilton, unpublished data) and anecdotal evidence of improvement in nesting success of the white-tailed tropicbird (N. Hamilton, pers. comm.).

Removal of the majority of the stray/feral cat population has been noticed by much of the community who have commented on the success of the campaign and appreciated the decline in cat numbers. The return to owners of captured domestic cats, when trapped, and discussion of the programme with the owners, has also received a positive response. Both these factors have resulted in the community at large having an optimistic and constructive view of the programme. The enthusiasm with which the general community has embraced the programme indicates that there will be further support which can only increase the probability of successful eradication (see Oppel et al., 2010).

The excellent achievements of the programme are the result of a substantial effort by a number of dedicated people, made possible, in part, because of funding. Feral cat eradication programmes that have failed in the past were usually attributed to lack of institutional and financial support (Campbell et al., 2011). Land management agencies on Christmas Island must secure the further funding required to guarantee that finances and effort expended to date have not been wasted, see the project to its successful conclusion and ensure conservation of biodiversity. Worldwide successful cat eradication campaigns have varied in cost from US$4–431/ha (in 2009 US$; Campbell et al., 2011). Even at the upper end of this investment range, feral cat eradication can still be a cost-effective strategy for preventing species extinctions on islands (Nogales et al., 2013). The cost of cat eradication on Christmas Island is likely to be towards the middle of the above range and estimated to cost a further US$2,000,000.

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